July 3, 1962 N. L. HALL 3,042,323

LIFTER-LINER LINING FOR ROTARY BALL MILLS

Filed Nov. 17, 1958

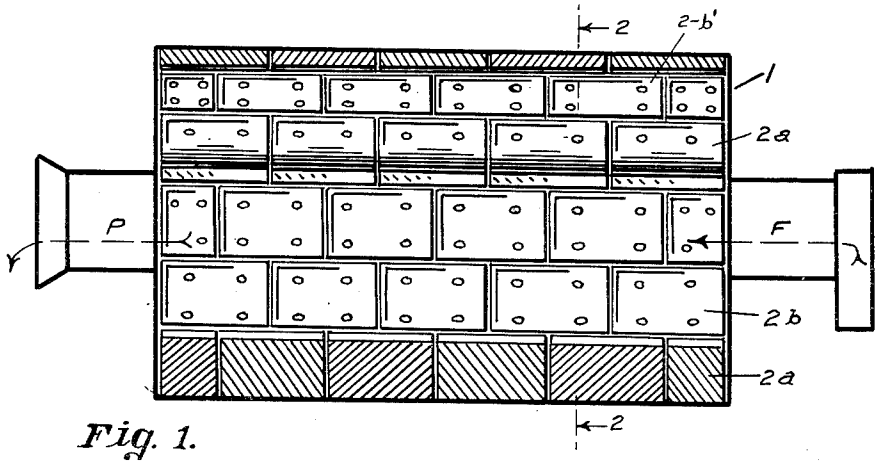



Fig. 1.

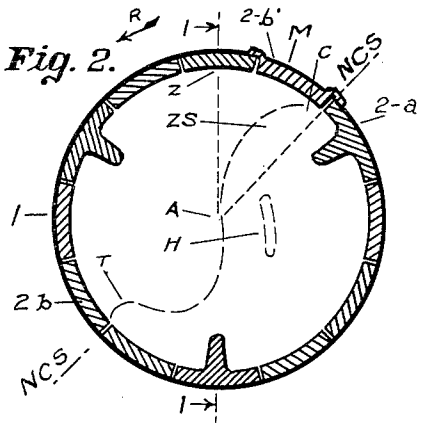



Fig. 2.

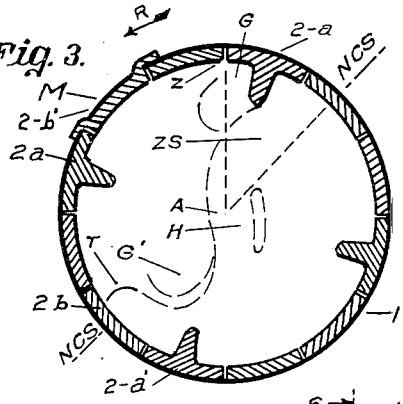



Fig. 3.

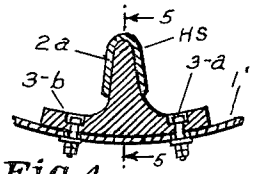



Fig. 4.

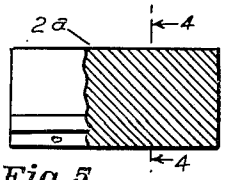



Fig. 5.

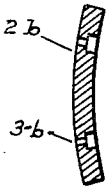



Fig. 6.

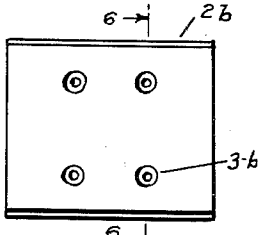



Fig. 7.

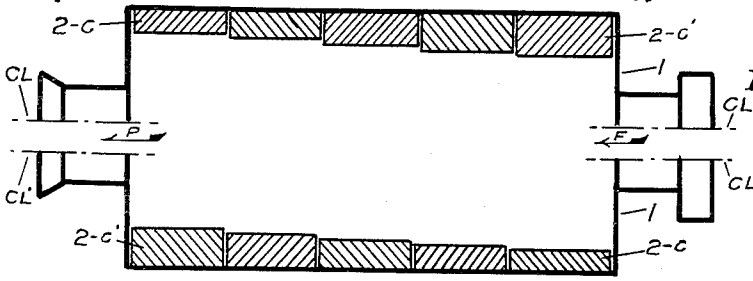



Fig. 8.

Fig. 9.

INVENTOR:

Newton L. Hall

United States Patent Office 3,042,323 Patented July 3, 1962



3,042,323

# LIFTER-LINER LINING FOR ROTARY BALL MILLS

Newton L. Hall, P.O. Box 83, Salt Lake City, Utah

Filed Nov. 17, 1958, Ser. No. 774,178
1 Claim. (Cl. 241—183)

This invention relates to rotary cylindrical ball mills used for the comminution or fine grinding of rock, ores, cements, or like materials.

The particular application as described herein, relates to the lifter-liner lining used in ball mills to provide a protective lining to the cylindrical shell of the mill caused from the destructive action and wear by the rotating mill load upon the interior surface of the mill shell or cylinder, and in addition thereto, the lifter-liner lining commands the load in its action within the rotating mill cylinder and over its operative cross section.

The term "ball mill" as used herein, applies to the class of tumbling mills in use as ball, tube, rod, or bar mills, the general term being used regardless of the type of grinding media employed within the load.

The term "lifter-liner" lining refers to the lifter sections of lining used in parallel lifter rows, being spaced between the rows of liner groups positioned intermediate to the lifter rows and serving primarily as a protective covering to the mill cylinder.

This application applies to "lifter" and "liner" sections of lining similar to the customary type of sectional linings which are of a size adapted to pass through the mill service manhole in ingress for installation within the cylinder, and for egress in removal or replacement. All sections of the lifter-liner lining are singularly independent and are firmly and detachably attached directly to the mill shell, with base plates formed to the shell curvature.

Ball mills have been universally adopted for the fine grinding of ores and cements. The rotating cylindrical mills vary in size from five to fourteen feet in diameter and in lengths of two diameters for ball mills, and several diameters for tube mills. Various capacities of mill loads are used depending upon the nature of the material being ground and the size of grind required for the product, the grind being either a wet or dry grind. The load can be circulating or batch loading, under open or closed circuit. The general average of mill loading being at 42 percent of the volumetric capacity of the mill and with a moisture content of 70 percent for a wet loading. A grinding media of metal balls are sized from one to four inches in diameter, the smaller ball being used for attritional and the larger ball for impact actions. A cubic foot of balls weigh about 300 pounds, the total weight for balls and mix, or pulp, averaging 400 pounds per cubic foot. As a general average, a ball mill feed of 4 to 8 mesh will be ground to a product of 250 mesh in screen size.

Ball mills rotate according to size from 35 r.p.m. to as low as 12 r.p.m. the general average for speed of rotation being 400 feet per minute of travel for the exterior perimeter of the load. The load under movement rises on the ascending side of the mill cylinder to a position of cascade slope which is approximately a slope of 45 degrees from the horizontal, and then descends from the crest into a sliding cascade reaching the toe of the load where it meets several actions forming reversals of directions and then combines with the ascending load to reach the cascade slope as before.

An increase of load rotation above the normal speed of action will cause the load to open above the line of cascade slope, separating the load parts and causing their



open rain upon the toe of the load, or against the bare mill lining which is in advance of the load toe.

This invention is designed to avoid a load separation above the cascade slope and aims to maintain a compact load in contact with itself during the entire load revolution.

The design of the mill cylinder avoids the use of obstructing features within the mill such as concentric shells, lugs, or baffle plates, and the mill cylinder is clear and imperforate, and utilizes the maximum cross section within the mill for operation to the fullest extent practicable.

The liner plates have a clear inner concaved surface and are without lugs, nodes, or undulations, or other deformations. The lifter plates are formed similar to the liner plates or sections, with an imperforate header portion extending radially inwards and towards the mill axis, the height of the header on the plate portion being between 5 and 15 percent of the mill diameter.

The header of the lifter plate provides the lifting feature of the lining, using a required number of lifter plate rows to produce the lift. The lifter plates are positioned in continuous and straight rows extending substantially from head to head of the mill interior. The several number of lifter rows required is more than two, but not many.

Three or four lifter rows will meet most requirements. A scattering of the lifter sections among the groups of liner sections may disrupt the general load action, and the lifter rows in straight, spaced, and continuous alinement are ideal. Variations may be made in the number of lifter rows used within the limitation herein and above expressed without departing from the spirit of the invention.

Lifter sections may be formed of various header heights, and placed in rows with the section of lowest height of header positioned at one end of the row and the next lifter adjoining being in succeeding heights from the lowest to the highest header height, or, the reverse, or combination of height arrangement may be used.

The header on the concaved surface of the lifter plate is a radial extension and forms the load lifting feature of the lifter plate. The height of the header determines the amount of load which can be received before it from the cascade near the toe of the load. A lifter plate header with a greater height will command a greater load before it than a header of less height, and a greater load will be carried by the higher header into the zenith space and then delivered as a sliding load portion from the cascade crest.

With a proper proportioning of rotating load to the mill volume, the variation of height of the lifter header will effect a classification between large and small parts of the mill load, extending the fines towards one end of the mill cylinder with the coarse parts at the opposite end, the action being true more with a granular than a wet loading.

The capacity of the cylindrical mill volume is taken up by a rotating mill load plus a vacant working space above the load cascade. A working ratio exists between the two parts of the mill volume, for an increase of the load volume will intrude upon the working space and reach a point wherein the merits of load action will decrease. This invention notes the fact that a common loading is at 42 percent of the mill volume, a condition that was primarily created through the fact that such mills operated with hollow axial trunnion bearings and the mill cylinder would voluntarily discharge at the lower level of the trunnion openings. Other mills, not

being limited, gorged their mills to a greater than half capacity. This invention has set the mean of good milling practice at a mill loading of 55 percent of the cylindrical mill volume, passing the load cascade over the full diametral length, and through the zenith space by virtue of the higher height of header on the lifter plate.

One of the objects of this invention is to provide a rotary ball mill cylinder of uniform diameter and clear interior with a circumferential interior lining placed in combination to develop mill cylinder wear protection, and, new and advanced milling and grinding results.

Another object is to utilize the sectional space of the mill cross section existing between the normal cascade slope of the rotating load and the vertical center line of the mill extending from the mill axis to the zenith of the mill interior, herein termed the zenith space.

Another object is to increase the mill loading towards a maximum of fifty five percent of the volumetric capacity of the mill cylinder, developing a cascade passing in descent above the axis of the mill cylinder, and creating a load portion in advance of the lifter header, to descend from the zenith crest as a sliding cascade along and upon the normal cascade, to strike the load toe in impact action.

Another object is to provide a cylindrical ball mill with related parts formed outside of the rotating load and leaving the interior space above the load open and unobstructed for mill load action.

Another object is to provide a ball mill cylinder of uniform diameter and clear interior, with interior lifter plates with headers in rows formed in combination of lifter plate sections with header heights measured between five and fifteen percent of the mill cylindrical diameter.

Other objects are: to develop a ball mill cylindrical lining which is of simple design and manufacture; one which affords good wearing qualities of the lining by placing lifter and liner parts in direct line rather than across the direction of mill load action; a lining which commands a mill load action over a major portion of the mill cross section; a lifter-liner lining which develops a variable load action over longitudinal portions of the mill load; the several features of improvement being developed with the adaptation of lifter-liner parts in combinations, to produce new and advanced milling and grinding results.

Other objects will be apparent as the invention is disclosed.

Referring to the drawings:

FIGURE 1 represents a longitudinal diagrammatical section of a mill shell, without load, taken on line **1—1**, of FIG. 2, showing the lifter-liner lining as arranged within the mill interior.

FIGURE 2 is a cross section, taken on line **2—2**, of FIG. 1, showing the lifter-liner lining as arranged with lifters in triple formation with one lifter in position approaching the cascade slope.

FIGURE 3 is a cross section, similar to FIG. 2, with the lifters arranged in quadrant formation and with one lifter in position approaching the zenith of the mill interior.

FIGURE 4 is a cross section taken on line **4—4** of FIG. 5, and showing a lifter as attached to a portion of a mill shell.

FIGURE 5 is a part side view and part section of the lifter section taken on line **5—5** of FIG. 4.

FIGURE 6 is a cross section of a liner section or plate taken on line **6—6** of FIG. 7.

FIGURE 7 is a side view of the inner circumferential face of a liner section or plate, shown in FIG. 6.

FIGURE 8 is a diagrammatical and longitudinal section showing one half only of a mill section in outline below the center line CL', or mill axis, with one single row of lifter sections with headers arranged in progressive formation from the lesser **2**–*c*, to the greater height **2**–*c'*, the increasing header height on the sections following in regular order extending from the feed end F, towards the discharge end P, of the mill section.

FIGURE 9 is a diagrammatical and longitudinal section showing of the upper half only, of a mill section in outline above the center line CL, similar to FIGURE 8, with one single row of lifter sections with headers, arranged in progressive formation from the greater **2**–*c'*, to the lesser crest height at **2**–*c*, the increase of height extending from the discharge end P, to the feed end F of the mill section. FIGURES 8 and 9 are structurally separate and distinct embodiments of each other.

Referring to FIGURES 1 and 2; the lifter plates **2**–*a* and liner plates **2**–*b* are of a size to pass through the mill service manhole M, for attachment to the mill shell by the bolts **3**–*a*, shown in recessed bolt holes **3**–*b*, in FIG. 4.

The lifter plates or sections, are in several continuous straight rows in triple or quadruple arrangement per mill and along the interior of the cylindrical mill shell, with the liner plates in groups interposed between the straight and parallel spaced rows of lifter plates. The combined lifter and liner extend over the entire interior cylindrical surface of the mill shell. This invention does not involve the head liners covering the mill heads.

The design shown in FIG. 2 has the lifter plates arranged in continuous and straight rows extending substantially from head to head of the mill interior, as shown in FIG. 1.

Lifter rows shown in cross section in FIG. 2 are arranged in triple alinement, and in quadruple alinement in FIG. 3.

An increase in the number of lifter rows adds lesser merit to the load action, and within limits, without departing from the spirit of the invention.

In FIGURES 2 and 3, the dotted line NCS denotes the approximate position of the cascade slope of the surface of the descending portion of the mill load, herein termed the "normal cascade slope. " The position of the normal cascade slope NCS, will average 45 degrees from the horizontal, and is the approximate position of the cascade slope of most loads regardless of the size of the mill diameter. The general shape of the surface of the cascade slope exposure of the roating mill load is similar to a monad curve, a convex curve above and a concave curve below the central position near the point of mill axis.

In FIGURE 2, the lifter with header **2**–*a* is in a position approaching the load crest C, at the normal cascade slope NCS, and in FIG. 3, the mill section is shown in an advanced position over the position shown in FIG. 2, showing the header portion of load G, carried above the normal cascade slope and towards the zenith Z, of the mill interior, allowing the unsupported header portion of load to be released then descend as a sliding cascade bearing upon the cascade surface of the load, and passing across the full diametral space to a position G', to strike the load toe T. A rotating mill load under normal mill actions, descends upon reaching the normal cascade slope and does not enter the zenith space ZS. Rotating mill loads under increased speeds may have the ascending mill load in open descent from the load crest as a cataracting fall. The herein invention provides for a compact load and avoids an open centrifugal descent of the load in its fall towards the load toe T.

An increase of header height will elevate the surface of the cascade and may pass the cascade surface above the central point of mill axis A, and also may have a heaving motion in time with the lifters and the load revolution. Practically all load actions are beneficial for grinding effects.

As the cascading load falls upon the header **2**–*a'* of the lifter plate which is entering the ascending load at T (FIG. 3), the direction of fall of the descending load is substantially in a direct line with the position of the

lifter header, and avoids a major cross action of wear from the falling load. The exposed projecting surface of the lifter header may be capped with a hard surfacing HS, as a further protection to the wear resisting qualities provided by the alloyed steel compositions of the lining plates.

In FIG. 4, a cross section of a single lifter plate is shown attached to a portion of a mill shell 1', by the attaching bolts 3–*a*, through the recessed bolt holes 3–*b*, and with the prolonged extension of the header 2–*a*, covered with wear resisting hard surfacing HS.

This invention provides lifter plates to the rotating mill load for engaging the load at distinct intervals rather than by forming the load engagements at numerous distributed points over the entire portion of the load which is in contact with the mill shell lining. The lift of the load by the lifter plates is concentrated at the lifter rows rather than over a lugged, or undulated surface of the liner plates. The prime service of the lifter plates with headers is to lift and regulate the mill load and to extend the load beyond the line of normal cascade slope and into the space, herein termed the zenith space ZS, a space normally unoccupied by the active load. The lifter plate serves to accommodate the mill load capacity upwards to a loading of 55 percent of the mill volume, altering the mill load actions over a greater portion of the mill cross section, with the descending portion G', reaching the load toe T, with an intermittent load impact action.

The prime service of the liner plates 2–*b*, is to protect the mill cylindrical shell and its lining from the destructive wear and action of the rotating mill load. The liner plates are of uniform thickness, with concave inner surface without deformations, lugs, or undulations, and, being of a single thickness, have an ease of manufacture.

Practically all lining parts for a ball mill are composed of hard iron, or alloyed steel as a combination of steel alloyed with chrome, manganese, nickel, or other suitable metals.

The radial height of the header on the lifter plate 2–*a*, determines the depth of the first portion of the load deposited by the cascade at the load toe and over the lifter plate header, affording a wear protection to the liner sections adjacent to the mill shell as under the rising load. A variation of header heights will alter and extend the cross section of the load, changing the shape and position of the heart space H, and enlarging the line of cascade with the development of the advanced crest G, to occupy the cross sectional segment between the normal cascade slope NCS, and the vertical center line passing through or above the axial center and to the zenith of the mill interior, herein termed the zenith space ZS. The conversion of that vacant space into an area of load action (without undue change of mill speed), as performed by the lifter plates and header, is one of the objectives of this invention.

The load action may be increased with an increase of mill speed, resulting in projecting the cascading portion of the load into a free and open descent, but within this invention such as action is avoided. A scattered cascade as a rainfall is out of abrasive contact within itself, and the load portions may fall ahead of the load toe and reach the uncovered mill lining with a destructive wearing force.

The design of this invention provides a compact mill load to act within and upon itself, as example: A mill load is frequently considered at its greatest efficiency at 42 percent of the volumetric capacity of the mill cylinder, and the design of this invention increases the mill capacity to volumes of 55 percent, the increased portion of the mill load, or its extension, receiving increased mill action by virtue of the height of the header on the lifter plate within the limits herein stated, providing for extra loading with load action, over the zenith space ZS, and the lengthened surface of cascade. The mill rotation is noted by the arrow R.

An increasing of the mill loading from 42 to 55 percent places the weight of the additional increased portion upon the mill trunnion bearings rather than upon the driving gear. An increase of mill loading above 55 percent of the mill volume is of doubtful merit when used on circulating loads. There is a practical limit for the extent of mill loading and the herein design of loading has reached that limit.

One of the objects of this invention is to provide a provision for a change of load action within a mill of cylindrical shell of uniform diameter and clear interior, by a variation of the radial height of the header on the lifter plate, the alteration of height being between the 5 and 15 percent limitation herein expressed. A lifter plate with header of greater height than 15 percent of the mill diameter will act as a diaphragm, serving to act in a separation, or divisions of the body of the load. Forming the header height to 5 percent or less, of the mill diameter, will cause the header to act as a lug rather than as a lifter on the header plate. This invention serves to maintain the mill load in action as a compact body.

Providing the cylindrical mill with lifter-liner lining of lifters arranged in various heights whereby the height of the header on the lifter plate will alter the rotating load action to develop similar actions compared to those developed in mill cylinders of other shape than the shape of the enclosing cylindrical shell, is an objective of this invention. A header of short height will open the load to a different cross section than a header of longer height; altering the positions of the ascending load next to the mill shell, the heart of the load, and the descending load as a cascade. The variations of cascade and load sections will change with each header height.

The height of the row of lifter plates with headers can vary from the shortest to the longest height, or, the header height variation may descend towards the cylindrical mill mid-section with the migration of the load parts placing the fines, or the coarse, portions to a desired position along the length of the mill cylinder, thereby developing grinding effects similar to cylindrical shell of conical shape, or, of different multiple diameters, and, maintaining the enclosing cylinder as a true cylindrical shape, the most practical shape for volume operation and comminution.

Metallurgical grinding prefers a limitation on the degree of fineness for the crush.

Cement grinding receives a beneficial result from extreme fines, and frequently can sacrifice the grade of fine grinding to receive in exchange a greater volume of mill capacity.

Many mill grinding operations are performed within an enclosed cylinder, and some mills will act erratically for no apparent reason. Upon opening the mill cylinder it is frequently observed that the fines will collect towards one end and the coarse at the other end of the mill cylinder. An adjustment of the header height on the lifter plate can control a load migration to develop an equable distribution of sized load over the full length of the mill interior, if such an operation is required.

The foregoing descriptions apply principally to mills grinding a dry ore which may have characteristics of movement and repose somewhat different to the actions of ore in a wet pulp; the ores may act in variations practically as a limpid and sluggish liquid or, as a freely flowing solution, and, the grip by the header of the lifter plate upon the loads will vary when in a static position. The wet ore will adjust its position within the revolving load more quickly than in a dry load, but each particle of load is subject to forces, gravitational, centripetal, and centrifugal, undergoing adjustments in each movement of the mill revolution, and a constant variation in element of

time is required to perform that regulation among the forces acting on the load. Each set formula for movement is dependent upon another set, consequently any set formula regarding movements in a ball mill must be considered only for that particular load, in texture, size of load, saturation, grind, and time of movement, etc. Ball milling is a complex action, it is not an absolute operation.

This invention maintains a compact load when under rotation at a normal speed of operation which is approximiately at 400 feet per minute of travel measured on the perimeter of the load, with variations of speed adjustment within 5 percent either above or below that normal action. An open or scattered load in a falling cataract is avoided. Lugs, nodes, or undulations on the concaved surface of the liner plate to grip the perimeter of the load are obviated by the service of the header on the lifter plate which provides a positive grip for the ascension of the load, disregarding any slip of load which may develop over the liner plates and between laterally adjoining lifter rows bordering the group of liner plates. The extension of the header on the lifter plate to heights up to 15 percent of the diametral measurement of the mill shell, not only affords a lift to the load portion before the header but also places that portion within the zenith space, a space above the normal cascade slope, and also carries the advanced load portion G to a position near the zenith area to descend in action as a sliding load portion, passing over a diametral length of cascade to strike the load which is near the toe at G', a zone of extreme load agitation, the features of novelty being developed by virtue of the diametral height of the header on the lifter plate.

In applicant's patented construction, U.S. Patent No. 2,868,463 for ball mill with load dispersion bar, the dispersion bar acts submerged near the heart of the rotating load, and under proper rotation and bar weight, the bar is submerged and does not act at the perimeter of the rotating load—in the application herein described, the lifter plates with headers operate outside of and at the perimeter of the rotating load—the comparative load actions are partially similar but not exactly alike.

The actions of the load near the load toe portion T are of extreme agitation, for all parts of the load in cascade must quickly and positively change direction of movement before ascending to the load crest C. Striking the toe portion of the load with the descending load portion G' is a critical impact action of novel merit, produced by virtue of the height of the header portion on the lifter plate. The increase of the active mill load to a near 50 percent capacity also increases the radial depth of the load toe T, a load location wherein the load of or near the toe is undergoing extreme agitation in reversals of movement.

I claim:

A lifter-liner lining for a horizontal rotary ball mill of uniform shell diameter, clear interior, and imperforate shell, open at both ends for respectively receiving and discharging material to be ground, comprising; sectional and circumferential lifter plates with imperforate headers extending consecutively within several spaced rows of straight alinement along the length of the interior of said mill shell, the headers of said lifter plates extending radially from the concaved inner surface of said lifter plates measured in magnitude between five and fifteen percent of the diametral measurement of said mill shell, said rows of lifter plates with headers being interposed between groups of uniform circumferential liner plates, said lifter plates with headers alined in regular rows with said headers being of diverse heights, said liner plate groups and said lifter plate rows, included in total combination a lifter-liner lining detachably attached directly to the interior of said mill shell and adapted to develop mill load actions to engage a composite circulating load of discrete material to be ground, said load actions being governed by the normal speed of mill and the diametral height of header on said lifter plates.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 1,921,672 | Haushalter | Aug. 8, 1933 |
| 2,186,164 | Brown | Jan. 9, 1940 |
| 2,268,661 | Kennedy | Jan. 6, 1942 |
| 2,456,266 | Gates | Dec. 14, 1948 |
| 2,611,546 | Posselt | Sept. 23, 1952 |
| 2,670,140 | Douglas | Feb. 23, 1954 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 166,073 | Austria | June 10, 1950 |
| 404,342 | France | Nov. 29, 1909 |